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International application number: PCT/US04/018763

International filing date: 15 June 2004 (15.06.2004)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/478,923
Filing date: 16 June 2003 (16.06.2003)

Date of receipt at the International Bureau: 23 August 2004 (23.08.2004)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

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APPLICATION NUMBER: *60/478,923*
FILING DATE: *June 16, 2003*
RELATED PCT APPLICATION NUMBER: *PCT/US04/18763*

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

60/478923 06/16/03

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TITLE OF THE INVENTION (280 characters max)

METHOD AND APPARATUS ENABLING FAST CHANNEL CHANGE OF COMPRESSED VIDEO

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 9 ☐ CD(s), Number

☐ Drawing(s) *Number of Sheets* 5 ☐ Other (specify)

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

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☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: ____.

Respectfully submitted,
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METHOD AND APPARATUS ENABLING FAST CHANNEL CHANGE OF COMPRESSED VIDEO

BACKGROUND OF THE INVENTION

Popular video compression standards, such as MPEG-2 and JVT/H.264/MPEG AVC use intra and inter coding. For proper decoding, a decoder decodes a compressed video sequence beginning with an intra-coded (I) picture, and then continues to decode the subsequent inter-coded (P and B) pictures. A Group of Pictures (GOP) may be comprised of an I picture and several subsequent P and B pictures. I pictures typically require many more bits to code than does a P or B picture of equivalent video quality.

When a receiver initially begins receiving a program on a particular channel, following a channel change or initial turning on of the receiver, it must wait until an I picture is received to begin decoding properly, which causes a delay. To minimize channel change delay in digital video broadcast systems, I pictures are typically sent frequently, for example every N pictures. For example, to enable ½ second delay (of the video compression portion of the system), it is common to use N=15 for 30 fps content. Because compressed I pictures are so much larger than compressed P and B pictures, this considerably increases the bitrate over what would be required if I pictures were not inserted so frequently.

Most broadcast systems transmit I pictures frequently, for example every ½ second, in order to limit the channel change delay time due to the video compression system.

In some systems, instead of sending full I pictures frequently, a technique called "progressive refresh" is used, where sections of pictures are intra coded. Typically, all macroblocks in the picture are intra-coded at least once during an N-picture period.

In the JVT/H.264/MPEG AVC compression standard, P and B pictures may be predicted using multiple reference pictures, including the pictures before a

preceding I frame. The standard identifies random access points as Independent Decoder Refresh, or IDRs, which constrains that no reference pictures before the IDR are used in predicting pictures following the IDR.

The JVT/H.264/MPEG AVC compression standard includes a tool called redundant pictures, defined in the standard as

> **redundant coded picture**: A coded representation of a *picture* or a part of a *picture*. The content of a redundant coded picture shall not be used by the *decoding process* for a *bitstream* conforming to this Recommendation I International Standard. A *redundant coded picture* is not required to contain all *macroblocks* in the *primary coded picture*. Redundant coded pictures have no normative effect on the *decoding process*. See also *primary coded picture*.

The slice header contains a **redundant_pic_cnt** field, whose semantics are defined as:

> **redundant_pic_cnt** shall be equal to 0 for slices and slice data partitions belonging to the primary coded picture. The redundant_pic_cnt shall be greater than 0 for coded slices and coded slice data partitions in redundant coded pictures. When redundant_pic_cnt is not present, its value shall be inferred to be equal to 0. The value of redundant_pic_cnt shall be in the range of 0 to 127, inclusive.

If the syntax elements of a slice data partition A RBSP indicate the presence of any syntax elements of category 3 in the slice data for a slice, a slice data partition B RBSP shall be present having the same value of slice_id and redundant_pic_cnt as in the slice data partition A RBSP.

Otherwise (the syntax elements of a slice data partition A RBSP do not indicate the presence of any syntax elements of category 3 in the slice data for a slice), no slice data partition B RBSP shall be present having the same value of slice_id and redundant_pic_cnt as in the slice data partition A RBSP.

SUMMARY OF THE INVENTION

The invention provides for allowing channel change delay at any desired rate at a lower bitrate than prior art methods. That is, the invention enables low delay channel change time in a compressed video broadcast system, while significantly reducing the bitrate over prior methods of enabling low delay channel change. Prior art systems broadcast I pictures frequently to enable channel change, for example every N pictures. In the present invention, normal I pictures are sent less frequently, and additional lower quality I pictures are sent more frequently.

DETAILED DESCRIPTION

In accordance with the principles of the present invention, a desired channel change delay can be achieved without requiring I pictures to be sent as frequently as is done in prior art systems. Instead, additional lower quality coded pictures, called the channel change stream, are sent in addition to the normal quality coded pictures. In the channel change stream, lower quality I pictures are sent at the desired channel change frequency, and are used at the decoder during the initial period following a channel change. Normal quality I pictures are sent in the normal stream at a lower frequency, and are used at the decoder once they are available. For example, consider a system which sends I pictures in the normal stream every N*K pictures and lower quality I pictures in the channel change stream every N pictures, with K > 1. Each coded picture in the channel change stream corresponds to normal stream coded pictures, so when a coded picture is present in the channel change stream, two coded representations of that picture are transmitted.

When a channel change occurs, a decoding system starts decoding the compressed video as soon as it receives an I picture, either from the normal stream or from the channel change stream. If the first I picture to arrive is from the normal stream, the decoder continues normally. However, if the first I picture to arrive is a lower quality I picture from the channel change stream, the decoder

decodes and uses the lower quality I picture. This causes lower quality video to be displayed until a normal quality I picture arrives. This period of lower quality video is not significantly noticeable to a viewer as it is of short duration and immediately follows a channel change. The human visual system takes some time to adjust to a new visual scene.

The channel change stream may either contain only lower quality I pictures, or may contain lower quality I, P and B pictures. The picture rate of the channel change stream may be lower than that of the normal stream. The lower quality pictures may be of the same resolution as the normal pictures but encoded at a lower bitrate, or may be of a lower resolution than the normal pictures. The bitstream size of the lower quality I coded pictures in the channel change stream are small compared with the size of normal quality coded I pictures in the normal stream. So even though additional coded representations of the same picture are being transmitted, overall bitrate savings occur because the size of a normal quality P or B picture plus the lower quality I picture is typically significantly less than that of a normal quality I picture alone.

If the channel change stream contains low quality I, P and B pictures, after a channel change the decoder system waits for the arrival of a lower quality I picture, and then it decodes and displays the lower quality pictures from the channel change stream until a normal quality I picture is received, at which point it switches to the normal quality stream.

If the channel change stream contains only I pictures, after a channel change the decoding system waits for the arrival of an I picture in either the normal stream or channel change stream. If the first I picture to arrive is in the channel change stream, the decoding system decodes and displays the lower quality I picture. Then this lower quality picture is stored in the normal decoder picture stores and the decoding system begins decoding the subsequent normal stream P and B pictures, using the lower quality I picture from the channel change stream as a reference. Because these normal quality P and B pictures were inter-coded based on prior pictures in the normal stream rather than the corresponding lower quality I picture from the channel change stream, this will cause some

decoding drift. Experiments have shown however, that the visual impact of such drift is small in this situation, because it lasts for only a short duration and immediately follows a scene change. The encoder can manage how much drift would occur and adjust coding parameters of the normal and/or channel change stream pictures appropriately such that drift does not exceed reasonable limits.

Figure 1 shows an encoding system and Figure 2 a decoding system that uses the same resolution images for both the normal stream and channel change stream. An encoder creates normal quality compressed video pictures for the normal stream, and in parallel an encoder creates lower quality compressed video pictures for the channel change stream. The figure shows two separate encoder blocks for the two encoder functions, but they could be performed using the same encoder device. The normal stream and channel change stream are multiplexed together and transmitted. In the decoding system, a demux separates the normal stream and channel change stream, and a selection is made as to whether the picture from the normal stream or the channel change stream should be sent to the decoder.

Figure 3 shows an alternate encoding system which applies a low pass filter to the input pictures prior to the lower quality encoder. Because the pictures in the channel change stream are coded at a relatively low bitrate, they may contain visible coding artifacts. By low pass filtering the images prior to encoding, some of these visible coding artifacts may be removed.

The multiplexor arranges the transmission time of the coded pictures such that the normal channel change stream I pictures are interspersed with the normal change stream coded pictures. The channel change stream coded picture should be transmitted near the time that the normal stream picture corresponding to the same input picture is transmitted, and before any normal stream pictures which are inter-predicted with respect to that picture.

Figure 4 shows an exemplary picture pattern for the case where only I pictures are included in the channel change stream, where N = 12 and K = 3. For a 24 fps sequence where channel change start periods of ½ second are desired, I pictures are inserted in the channel change stream every 12 pictures. I pictures

are inserted in the normal stream every 36 pictures.

Consider the case where a receiver tuned in to the channel while picture 5 was being received. The receiver would then wait until the first I picture in the channel change stream arrived, which is 12 in the channel change stream, and decode and display it. The decoded lower quality picture 12 from the channel change stream would then be placed in the decoder's picture store, and used in decoding pictures 12-23 from the normal stream. These decoded pictures will contain drift. When picture 24 arrives, the receiver may either choose to decode the normal stream's picture 24 or the channel change stream's picture 24. This could either be a receiver end decision, or a preference could be signaled by the encoder in the bitstream, based on which one will yield less drift. The normal stream's pictures 25-35 are then decoded, still with drift. Once the normal stream's picture 36 is received, which is an I picture, the decoder can start decoding properly without drift for all subsequent pictures. From the viewer's perspective, for a short period after a channel change, up to 1.5 seconds, lower quality video is displayed, and then normal quality is displayed.

Bitrate savings versus a prior art system is achieved because the large normal stream I pictures are sent less frequently that they would be sent in a prior art system. The lower quality I pictures sent in the channel change stream are much smaller than the normal quality I pictures. An encoding system may send the lower quality I pictures in the channel change stream as frequently as desired, and with any pattern. I pictures in the normal stream also need not follow a regular pattern, and for example may be inserted whenever a scene change occurs. An encoding system does not need to insert channel change stream I pictures if the distance between I pictures in the normal stream does not exceed a desired value. The encoding system may choose to insert I pictures in the channel change stream whenever necessary to maintain a maximum I picture spacing, associated with a desired channel change delay limit.

The channel change stream may contain pictures of different resolutions. For example, some of the I pictures in the channel change stream may be of the same resolution as the normal stream and others may be at a lower resolution.

Or two or more different lower resolutions for pictures in the channel change stream may be used.

In order to reduce the drift that occurs when decoding a normal stream picture using a channel change stream picture as a predictor, the encoder can restrict the range of allowable reference pictures for the P and B pictures that follow the picture that corresponds to the channel change stream I picture. In the JVT/H.264 video compression system, P and B pictures may be predicted using multiple reference pictures, which provides a coding efficiency advantage over using a single reference picture. For the example in Figure 4, a restriction may be imposed such that pictures 12-23 in the normal stream may not use reference pictures prior to picture 12. If this restriction were not imposed, more drift will occur following a channel change. For example, if picture 15 was predicted from both pictures 12 and 9, and a channel change occurred while picture 5 was being received, the decoding system would have a representation of picture 12, from the channel change stream I picture 12, but would not have any representation of picture 9. This could lead to a significant reduction in visual quality when decoding pictures 13-23. However, if a restriction were imposed that picture 15 be predicted only from picture 12, this significant drift can be avoided, with a small penalty in the coding efficiency of picture 15.

Figure 5 shows an encoding system and Figure 6 a decoding system that use lower resolution images for lower quality pictures in the channel changes stream than for the normal pictures. For example 704x480 pixels could be used for the normal pictures and 352x240 pixels for the channel change pictures. The input pictures are encoded normally, and are resized to a lower resolution and encoded at that lower resolution. The normal stream and channel change streams are multiplexed together and transmitted. In the decoding system, a demux separates the normal stream and channel change stream, and a selection is made as to whether the picture from the normal stream or the channel change stream should be decoded and displayed. If the channel change stream is decoded and displayed, the decoded picture is put into the normal stream decoder's picture store for use in decoding subsequent normal stream coded pictures. Although separate blocks are provided in the figure for the normal decoder and lower

quality decoder, both functions may be performed using a single device.

In the decoding system, following a channel change, lower quality video is initially displayed, and once an I picture in the normal stream is received, normal quality video begins to be displayed. The abrupt transition from lower quality video to normal quality video may be more noticeable to a viewer than the lower quality video itself. To reduce the abruptness of the transition, a postprocessor may be added following the decoder to filter the decoded pictures. The filter strength could be adjusted over several pictures, to gradually increase the resolution or quality of the decoded pictures.

Figure 7 shows a decoding system which incorporates a post processing filter. A post processing function may also be added following the lower quality decoder to hide compression artifacts.

There are several possible ways in which the multiplexing of the normal steam and channel change stream may be performed. To enable a backwards compatible system where the normal stream can be decoded without alteration to existing decoders, one method to is place the channel change stream's lower quality coded pictures in user data associated with the corresponding picture of the normal stream. This method allows the decoding system to identify the picture time of a channel change stream coded picture. If this method is used, an alteration to the unique picture start code of the coded pictures in the channel change stream is necessary, perhaps using bit or byte stuffing, to help the normal decoder avoid detecting the picture start code of the channel change stream picture inside of the user data. The bit or byte stuffing procedure would be reversed in the decoding system, before passing data to a standards compliant decoder.

An alternative multiplexing method is to use a different PID for the channel change stream than for the normal stream. In this case, the channel change stream will need to include timing information for the coded pictures, synchronized with the normal stream pictures. Also, an association must be made between the PIDs of the normal stream and the channel change stream.

If the JVT/H.264/MPEG AVC compression standard is used in this system, and the resolution of the normal pictures and channel change pictures are identical, the redundant pictures syntax of JVT could be used for coding the channel change pictures, by setting the **redundant_pic_cnt** field in the slice header to 1 for the channel change pictures. In this case, in the decoding system, the channel change stream pictures can be identified by searching for pictures containing a **redundant_pic_cnt** field in the slice header equal to 1.

PictureNum	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Normal	I	B	B	P	B	B	P	B	B	P	B	B	P	B	B	P	B	B	P	B	B	P	B	B	P
ChannelCh	I												I												I

PictureNum	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Normal	B	B	P	B	B	P	B	B	P	B	B	I	B	B	P	B	B	P	B	B	P	B	B	P
ChannelCh																								I

Figure 4. Example Picture Pattern

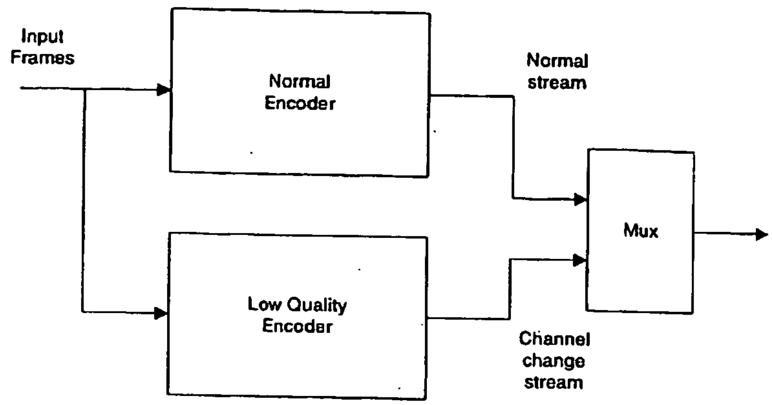

Figure 1. Encoder with same resolution for channel change stream

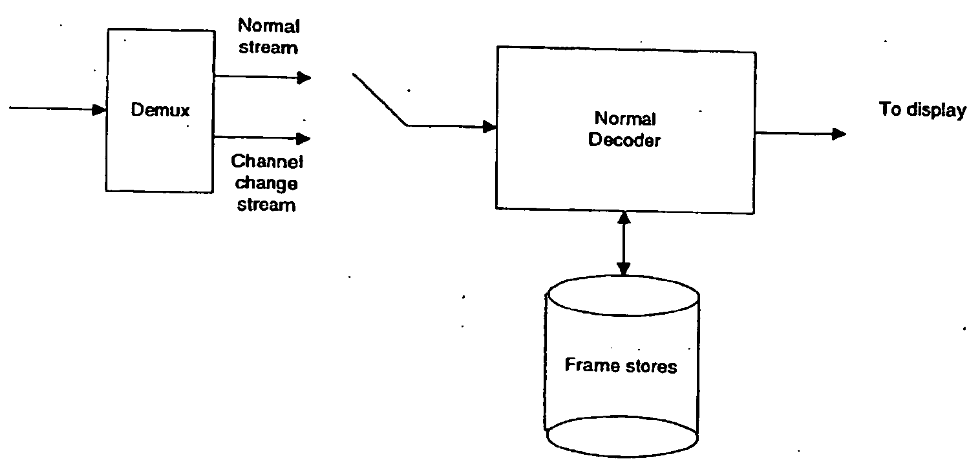

Figure 2. Decoder with same resolution for channel change stream

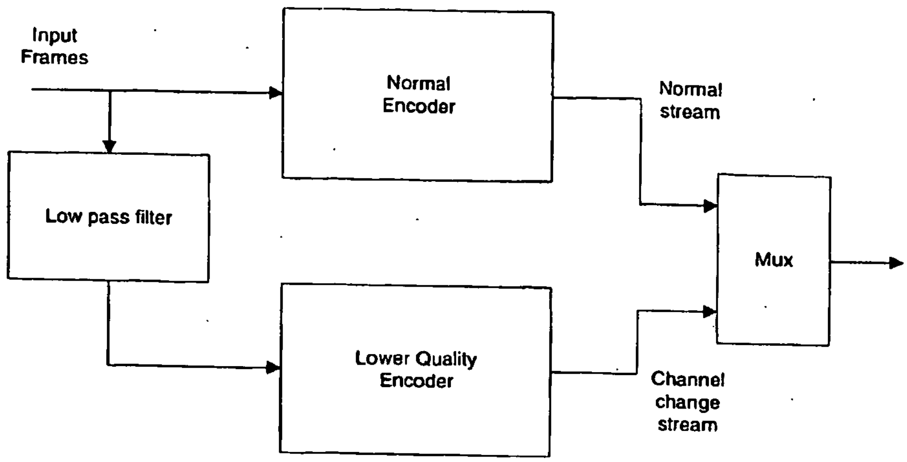

Figure 3. Encoder with filtered channel change stream

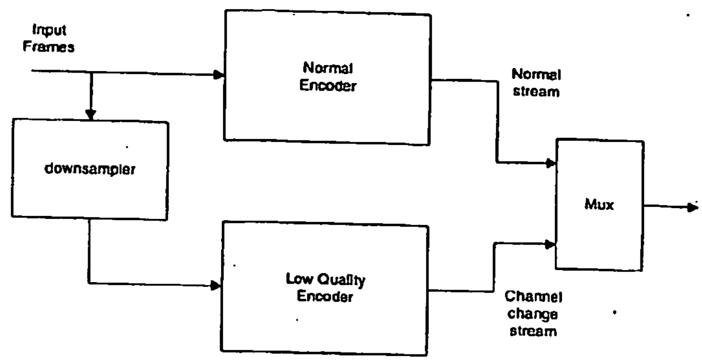

Figure 5. Encoder with downsampled
channel change stream

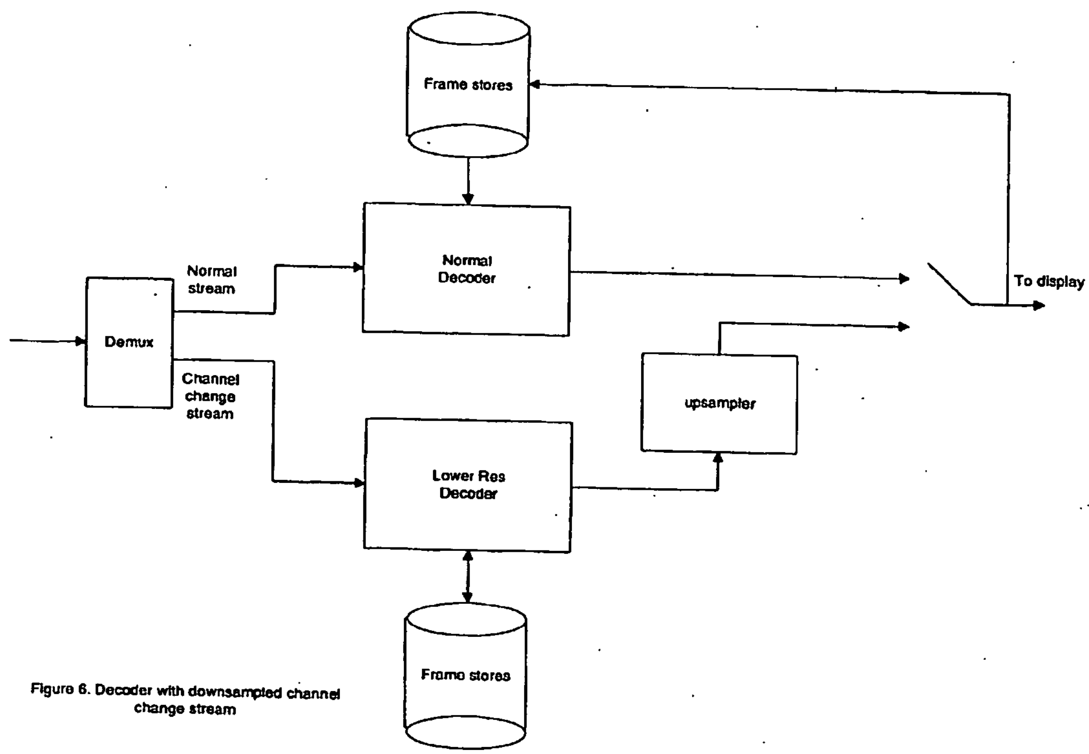

Figure 6. Decoder with downsampled channel
change stream

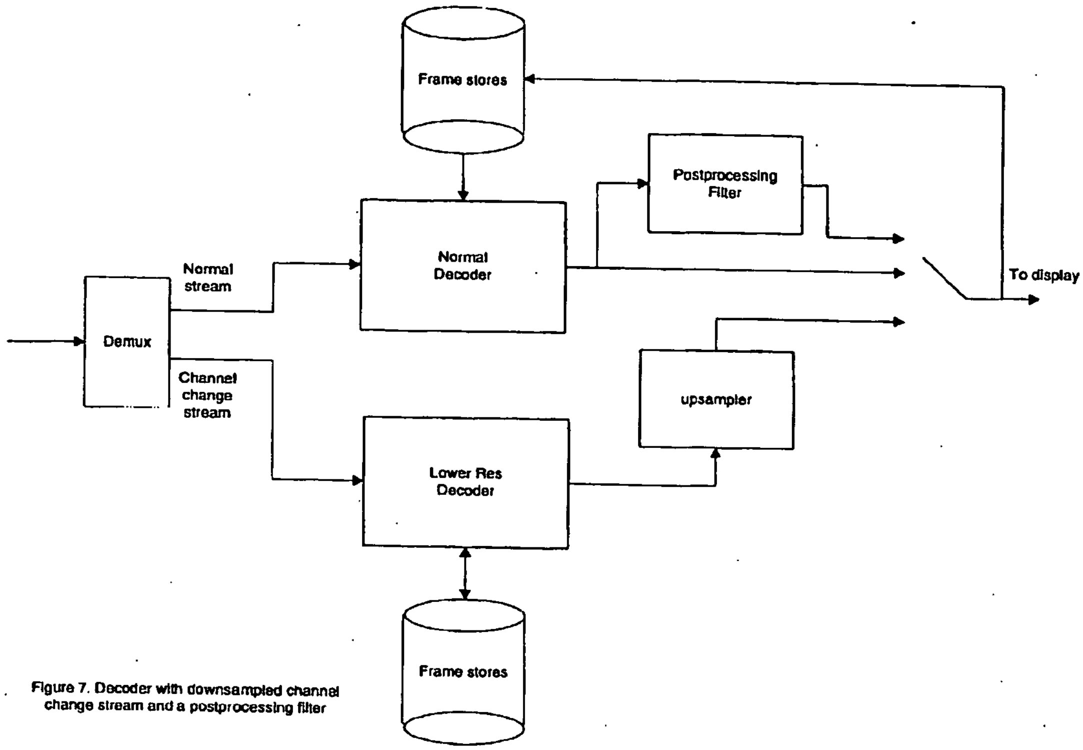

Figure 7. Decoder with downsampled channel change stream and a postprocessing filter

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